OPTICAL SYSTEM WITH DISPERSION COMPENSATION

[0001] This application is a continuation-in-part of U.S. patent application Ser. No. 16/609,716, filed Oct. 30, 2019, which is a national stage application, filed under 35 U.S.C. § 371, of International Patent Application No. PCT/US18/53192, filed Sep. 27, 2018, which claims the benefit of U.S. provisional patent application No. 62/607,908, filed on Dec. 19, 2017, each of which are hereby incorporated by reference herein in their entireties.

BACKGROUND

[0002] The present disclosure relates generally to optical devices, including dispersion compensation structures and methods for optical reflective devices having holographic optical elements.

[0003] Dispersion may cause chromatic aberrations in optical devices. These chromatic aberrations can have a degrading effect on an image of an optical reflective device. Accordingly, improved methods for correcting the effects of dispersion and optical reflective devices that mitigate the degrading effects of dispersion on reflected images are desired.

SUMMARY

[0004] The described features generally relate to one or more improved methods, systems, or devices for performing dispersion compensation. Holograms may be implemented within optical media as holographic optical elements. A holographic optical element may be substantially achromatic, sustaining a reflective angle independent of the wavelength of incident light. These holographic optical elements may be used in an optical device (e.g., an optical reflective device). Light traversing certain dispersion boundaries (e.g., air-to-projection coupling element, air-to-waveguide substrate, air-to-waveguide grating medium, waveguide substrate-to-air, waveguide grating medium-to-projection coupling element, waveguide grating medium-to-coupling element, etc.) of the optical device may exhibit waveform separation across disparate frequencies of the light.

[0005] A dispersion relationship between an index of refraction of one medium and an index of refraction of another medium for disparate frequencies may be used in techniques to compensate for chromatic dispersion of light in the optical device. Dispersion compensation techniques using the dispersion relationship may be applied to determine holograms that compensate for the chromatic dispersion effects of certain dispersion boundaries. A resulting holographic optical element may substantially approximate desired achromaticity associated with use of the holographic optical element in an optical device and/or a particular operating environment (e.g., where projection optics are used, where edge coupling is used, and/or in a fluid medium such as air or water).

[0006] In some examples, the holographic optical element includes a set of different holograms in a grating medium. Each hologram in the set may have a corresponding grating vector with a grating frequency (magnitude) and direction. The directions of the grating vectors may vary as a function of the grating frequency. Different holograms in the set may diffract light in a particular direction so that the light emerges from a boundary of the grating medium in a single given direction regardless of wavelength (e.g., perpendicular to the boundary). A prism may be used to couple light into the grating medium. The prism may be formed using materials having dispersion properties that are similar to the dispersion properties of the grating material. The prism may have an input face that receives perpendicular input light. The prism may include multiple portions having different refractive indices if desired. The prism may include two, three, or more than three stacked wedges formed from different materials. Interfaces (e.g., surfaces) between the wedges may be curved and/or tilted in multiple directions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] A further understanding of the nature and advantages of implementations of the present disclosure may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

[0008] FIG. **1** is a diagram of an illustrative head mounted display (HMD) in which the principles included herein may be implemented in accordance with some embodiments.

[0009] FIG. **2**A is a diagram illustrating reflective properties of an illustrative skew mirror in real space in accordance with some embodiments.

[0010] FIG. **2**B illustrates an illustrative skew mirror in k-space in accordance with some embodiments.

[0011] FIG. **3** is a diagram of illustrative skew mirrors in k-space and real space that may be oriented in a particular direction in accordance with some embodiments.

[0012] FIG. **4** is a diagram of an illustrative skew mirror in k-space and real space that shows how gratings in the skew mirror may be Bragg matched to some incident light in accordance with some embodiments.

[0013] FIG. **5** is a diagram of an illustrative skew mirror in k-space and real space that may be subject to material dispersion in accordance with some embodiments.

[0014] FIG. **6** are illustrative plots of skew mirror performance showing how an illustrative skew mirror of the type shown in FIG. **5** may be provided with gratings having skew axes that vary as a function of grating magnitude to compensate for material dispersion in accordance with some embodiments.

[0015] FIG. **7** is a side view of an illustrative input prism and an illustrative skew mirror having gratings with skew axes that vary as a function of grating magnitude to compensate for material dispersion in accordance with some embodiments.

[0016] FIG. **8** is an illustrative plot as skew angle as a function of grating magnitude for an illustrative skew mirror of the type shown in FIG. **7***in* accordance with some embodiments.

[0017] FIGS. **9**-**12** are side views of illustrative input prisms having different regions with different dispersion characteristics in accordance with some embodiments.

DETAILED DESCRIPTION

[0018] An optical head-mounted display (HMD) is a wearable device that has the capability of reflecting projected